8:30 to 11 P.M., to afford a convenient opportunity for viewing the collections.

On Friday afternoon at 4 o'clock an illustrated public lecture complimentary to the citizens of Washington was given at the Lafayette Opera House, by Professor John Hays Hammond, on 'King Solomon's Mines, or the Mines of Ophir.'

On Friday evening the trustees of the Corcoran Art Gallery and the local committee tendered a reception to the visiting members of the association and the affiliated societies at the Corcoran Art Gallery, from 8:30 to 11 o'clock. On Friday evening also was held the dinner of the American Alpine Club.

On Saturday morning at 10 o'clock the President of the United States received the members of the A. A. A. S. and affiliated societies at the White House.

Resolutions of thanks for courtesies extended were offered by Ex-President Minot and unanimously adopted at the closing general session. The institutions and individuals to whom the association was especially indebted include: Columbian University, Cosmos Club, Local Committee and its secretary (Dr. Benjamin), St. Matthew's Church, Georgetown University, Caroll Institute, Press of Washington, Trustees of Corcoran Art Gallery, the President of the United States, secretary of the Smithsonian Institution, acting director of the U. S. National Museum, director of the Naval Observatory, U. S. commissioner of Fish and Fisheries.

At the meeting of the general committee on Thursday evening it was decided to hold the next meeting of the association in St. Louis during convocation week, 1903–4, and to recommend Philadelphia as the place of the following meeting. The following were elected officers for the St. Louis meeting:

President—Carroll D. Wright, Washington.

Vice-Presidents—Section A, Mathematics and Astronomy, O. H. Tittmann, Washington; B, Physics, E. H. Hall, Harvard University; C, Chemistry, W. D. Bancroft, Cornell University; D, Mechanical Science and Engineering, C. M. Woodward, Washington University; E, Geology and Geography, I. C. Russell, University of Michigan; F, Zoology, E. L. Mark, Harvard University; G, Botany, T. H. Macbride, University of Iowa; H, Anthropology, M. H. Saville, American Museum of Natural History; I, Social and Economic Science, S. E. Baldwin, New Haven; K, Physiology and Experimental Medicine, H. P. Bowditch, Harvard University.

Permanent Secretary—L. O. Howard, Cosmos Club, Washington.

General Secretary—Chas. W. Stiles.

Secretary of the Council—Chas. S. Howe, Case School.

Secretaries of the Sections.—Section A, Mathematics and Astronomy, L. G. Weld, University of Iowa; B, Physics, D. C. Miller, Case School; C, Chemistry, A. H. Gill, Massachusetts Institute of Technology; D, Mechanical Science and Engineering (none proposed); E, Geology, G. B. Shattuck, Baltimore; F, Zoology, C. Judson Herrick, Denison University; G, Botany, F. E. Lloyd, Teachers College, Columbia University; H, Anthropology, R. B. Dixon, Harvard University; I, Social and Economic Science, J. F. Crowell, Washington; K, Physiology and Experimental Medicine, F. S. Lee, Columbia University.

Treasurer.—R. S. Woodward, Columbia University, New York, N. Y.

Henry B. Ward,
General Secretary.

The University of Nebraska.

MODERN TENDENCIES IN THE UTILIZATION OF POWER.*

It has been stated that to the construction and perfection of her machinery, more than to any other cause, may be ascribed the present commercial supremacy of the United States.

Be that as it may, the economical production of her manufactures and the convenient adaptations of time and labor

* Address of the chairman of Section D, Engineering and Mechanical Science, and vice-president of the American Association for the Advancement of Science. Read at the Washington meeting, December 29, 1902.

saving devices in all the various lines of constructional work have certainly exerted a wonderful influence in the upbuilding of her industries.

Specialization in the manufacture of machine tools and labor-saving devices has followed closely the segregation of processes in other lines of industry, and thus there has been created a multitude of special machines, each designed to perform some single and often very simple operation.

Among other significant features the present tendency in the development and use of this class of machinery is marked by the adaptation of compressed air and the application of electric power to machine driving. In the use of compressed air, the facility of adaptation to various requirements which are in many cases additional to the supply of motive power, is a valuable feature peculiar to this system and one which is susceptible of extension along many lines.

The labor cost in most machine shops and other works is so much greater than the cost of power, that any expedient by which the labor cost may be appreciably reduced is justified, even though the efficiency of the agent itself be low. Whenever new methods or agencies cause an increased production with a given outlay for labor, we shall find these methods superseding the old, even though the cost of the power required be greater than before. The saving of power is a consideration secondary to the advantages and economical output obtained by its use.

While economy in the use of power should therefore be secondary to increased output, yet careful attention to details will often greatly reduce the useless waste of power.

Engineers have recognized for some time past that there is a very great percentage of loss due to shaft friction, which, in railroad and other shops where the buildings are more or less scattered, may be as great as 75 per cent. of the total power used. In two cases known to the speaker these losses are 80 and 93 per cent., respectively. In the ordinary machine shop this loss will probably average from 40 to 50 per cent. No matter how well a long line of shafting may have been erected, it soon loses its alignment and the power necessary to rotate it is increased.

In machine shops with a line of main shafting running down the center of a room, connected by short belts with innumerable counter-shafts on either side, often by more than one belt and, as frequently happens, also connected to one or more auxiliary shafts which drive other countershafts, we can see why the power required to drive this shafting should be so large. There is no doubt, however, that a large percentage of the power now spent in overcoming the friction of shafting in ordinary practice could be made available for useful work if much of the present cumbrous lines of shafting were removed.

Manufacturers are realizing the loss of power which ensues from the present system of transmission, and we find a general tendency to introduce different methods by which a part of this loss will be obviated. Among these are the introduction of hollow and lighter shafting, higher speeds and lighter pulleys, roller bearings in shaft hangers, and the total or partial elimination of the shafting.

Independent motors are often employed to drive sections of shafting and isolated machines, and among these we find steam- and gas-engines, electric motors, compressed air and hydraulic motors, although the latter have not been used for this purpose to any appreciable extent.

In the choice of motors, until quite recently the steam-engine has heretofore been

used, especially where the units are relatively large. An interesting example of this is noted in the sugar refinery of Claus Spreckles, in Philadelphia, in which there are some 90 Westinghouse engines about the works, many of them being of 75 and 100 horse-power each, others are of 5 and 10 horse-power only. A similar subdivided power plant involving 42 engines was erected several years ago at the print works of the Dunnell Co., Pawtucket, R. I.

It was only a comparatively few years ago when several large and economical Corliss engines were replaced at the Baldwin Locomotive Works by a greater number of small, simple expansion engines, which actually required about 15 per cent. more steam per horse-power-hour than the Corliss engines. This loss, however, was only apparent, for by increasing the number of units and locating them at convenient centers of distribution much of the shafting and belting could be dispensed with and an actual saving was obtained. Later, these simple engines were replaced by a number of compounds, some eighteen being in service; subsequent tests on these showed a saving of 36 per cent. over that obtained by the use of the simple engines.

More recently, however, the electric motor has superseded the steam-engine for this work, as its economy and convenience over the latter are now thoroughly recognized.

The statistics of American manufacturing compiled by Mr. T. C. Martin for the United States Census Office, show that at the time of the last census, in 1900, electric power was less than five per cent. of all that was in use in such plants, or about 500,000 horse-power out of a total of 11,000,000; but, as Mr. Martin states, things are to be judged by tendencies rather than by the *status quo,* and these electric motor figures exhibit an increase of 1,900 per cent. during the decade.

The introduction of the electric motor in machine shops and factories was at first looked upon with disfavor and was opposed by many manufacturers, but the innovation obtained a foothold, and advantages which were at first unforeseen were found to attend its use, so that now it is being very generally adopted for a wide variety of work.

A considerable difference of opinion exists as to whether individual motors should be used with each machine, or whether a number of machines should be arranged in a group and driven from a short line shaft.

There are well-defined conditions to which each system is best adapted, but there are wide limits between which there appears to be no general rule, and we find both methods occupying the same field.

For isolated machines and for heavy machines that may be in occasional use the individual motor is particularly well adapted, as it consumes power only when in operation. It is, however, necessary that each motor thus connected shall be capable of supplying sufficient power to operate its machine under the heaviest as well as lightest loads. In certain cases, moreover, the load is liable to very great irregularity, as for instance in metal-working planers, in which the resistance offered by the machine at the moment of reversal of the platen is far higher than at other times, and may be so great as to endanger the armature of the motor. Under these conditions it is necessary to use a motor of much larger capacity than the average load would indicate.

Fortunately with electric motors the rated capacity is usually less than the safe maximum load, which is determined either by the heating of the conductors, tending to break down the insulation, or by ex-

cessive sparking at the brushes. For momentary overloads relatively large currents may pass through the coils without injury to the insulation, since the temperature effect is cumulative and requires time for its operation. However for continuous periods of considerable length it is usually unsafe to operate the motor much above its rated output.

Ordinarily in machine-driving the motor is shunt-wound, and the current through the field-coils is constant under all conditions of load; but to obtain the best results with that class of machinery in which the load is intermittent and subject to sudden variations, the motor should be compound-wound so as to increase the torque without an excessive increase of current in the armature.

In many cases with individual motors, owing to wide variations in power required, the average efficiency of the motor may be very low; for this reason a careful consideration of the conditions governing each case indicates that for ordinary machine-driving, especially with small machines, short lengths of light shafting may be frequently employed to good advantage, and the various machines, arranged in groups, may be driven from one motor. By this method fewer motors are required, and each may be so proportioned to the average load that it may run most of the time at its maximum efficiency.

When short lengths of shafting are employed the alignment of any section is very little affected by local settling of beams or columns, and since a relatively small amount of power is transmitted by each section, the shaft may be reduced in size, thus decreasing the friction loss. Moreover, with this arrangement, as also with the independent motor, the machinery may often be placed to better advantage in order to suit a given process of manufacture; shafts may be placed at any angle without the usual complicated and often unsatisfactory devices, and a setting-up room may be provided in any suitable location as required, without carrying long lines of shafting through space. This is an important consideration, for not only is the running expense reduced thereby, but the clear head-room thus obtained, free from shafting, belts, ropes, pulleys and other transmitting devices, can be more easily utilized for hoists and cranes, which have so largely come to be recognized as essential to economical manufacture.

In arranging such a system of power distribution the average power required to drive is of as much importance as the maximum, for in a properly arranged group system the motor capacity need not be the equivalent of the total maximum power required to operate the several machines in the group, but may be taken at some value less than the total, depending upon the number of the machines and the average period of operation. On the other hand as already shown, the motor capacity of independently driven machines must not only equal the maximum power required to drive the machine at full load, but it must be capable of exerting a greatly increased momentary torque. In any case large units should be avoided, for the multiplication of machines driven from one motor entails additional shafting, countershafts and belting which may readily cause the transmission losses to be greater than those obtained with engines and shafting alone, besides frustrating some of the principal objects of this method of transmission.

As far as the efficiency of transmission is concerned, it is doubtful whether, in a large number of cases, motor-driving *per se* is any more efficient than well-arranged engines and shafting.

As already pointed out, the principal

thing to be kept in mind is a desired increase in efficiency of the shop plant in turning out product, with a reduction in the time and labor items, without especial reference to the fuel items involved in the power production.

On account of the subdivision of power which results from the use of many motors, there is less liability of interruption to manufacture, and in case of overtime it is not necessary to operate the whole works, with its usual heavy load of transmitting machinery.

Another advantage is the adaptability to changes and extensions; new motors may always be added without affecting any already in operation, and the ease with which this system lends itself to varying the speed of different unit groups is a very potent factor in its favor.

One serious obstacle to the use of connected motors with machine tools is the difficulty of obtaining speed variation, which is so necessary with a large proportion of the machines in common use. A certain amount of variation can be obtained by rheostatic control—a wasteful method; or by using a single voltage system with shunt field regulation; but the variation in either case is very limited. This, however, may be increased by using a double commutator if space will permit.

The three-wire, 220-volt system offers many advantages for both power and lighting systems, and is very frequently employed. Variations of speed may be obtained with this system by using a combination of field regulation with either voltage, and, in rarer cases, the use of a double commutator motor.

A method which has been used recently with considerable satisfaction involves the use of a three-wire generator, with collector rings connected to armature winding similar to that of a two-phase rotary converter. Balancing coils are used, and the middle points of these are connected to the third wire, which is thus maintained at a voltage half-way between the outer wires. This system is simple and economical, and possesses all the advantages of the ordinary three-wire method; it permits similar variations in speed by field regulation with either voltage; and if still wider ranges are desired a double commutator motor may also be used.

In other recent installations the four-wire multiple voltage system is used, which permits of very wide variations of speed in the operation of the tool. This system gives excellent results and removes one of the objections urged against direct-connected motor-driven tools, namely, that such machines are not sufficiently flexible in regard to speed variation, and that such variation can only be obtained by throwing in resistances which cut down the efficiency of the motor, or by varying the strength of field which reduces the torque.

The multiple voltage system, however, has some serious disadvantages. It can not usually be operated from an outside source of power without rotary transformers; the generating sets and switch-board are complicated and the total cost of installation is expensive; yet with these drawbacks the system is growing in favor, as it has manifest advantages which outweigh the objections.

The storage battery has been used to some extent to obtain multiple control and is suggestive of interesting possibilities, but in its present form it is not altogether desirable for machine tools.

In many of the larger sizes of certain metal-cutting machines it is probable that marked changes will be produced in the immediate future, and the indications are that direct-connected motors with wide variations of speed and power will be incorporated in the new designs.

The recent improvements in the manufacture of certain grades of tool steel have shown indisputably that the present designs of machine tools are not sufficiently heavy to stand up to the work in order to obtain the economy of operation which results from the use of such steels. Higher speeds, heavier cuts and greater feeds may be obtained if the machines will stand the strain, but in most cases the capacity of the machine is not commensurate with the ability of the tool to remove metal. With cutting speeds of 100 to 200 feet per minute, it is evident that the power requirements will be much greater than for the ordinary machines of to-day, which have a cutting speed of from 10 to 30 feet per minute. As an illustration of what can be done with these new tool steels the speaker was recently shown some steel locomotive driving-wheels which had been turned up in two hours and forty minutes, whereas the regular time formerly required was not less than eight hours. In this case even better results could have been obtained, but the belts would not carry the load.

Here then we find an interesting field for the direct-connected motor with ample power and speed variation for any work which it may be called upon to perform.

While the preference is easily given to continuous-current motors for the purposes of machine driving, yet we find alternating current motors used to a considerable extent, the proportion of motors in service being about one to five in favor of the continuous-current motor. Both synchronous and induction motors are employed, but the advantages possessed by the latter cause this type to be preferred, although in long-distance transmissions, both types should be used in order to obtain satisfactory regulation. As shown by Mr. H. S. Meyer,* the induction motor can readily be worked at variable speeds, which is accomplished in three different ways: (1) by rheostatic control, which is decidedly the cheapest and easiest method to manipulate; (2) by varying the impressed voltage, which, however, necessitates the use of a transformer or compensator with variable ratio; this is very inefficient at the lower speeds and can only be used under certain conditions; and (3) by altering the number of poles, which is mechanically very complicated, but where the speed variation is only one half or one quarter it may be used efficiently.

One serious disadvantage met with in all induction motors is the lag produced by self-induction, and its reaction on the circuit. This lag is particularly unsatisfactory with intermittent service, such as machine driving, where the motors have to run under light and variable loads; in such cases the power factor is probably not over 60 or 70 per cent.

Reference has been made to the use of compressed air and its facility of adaptation to various requirements, but it is evident from an inspection of some of the devices in use that enthusiasm for new methods, rather than good judgment, has controlled in many of its applications.

For some years compressed air was used only in mines, where it produced marked economies in underground work. Later, compressed air was introduced into manufacturing lines, and to-day its use in railroad and other machine shops, boiler shops, foundries and bridge works is being widely extended. In the Santa Fe Railroad shops at Topeka there are over five miles of pipe in which compressed air is carried to the different machines and labor-saving appliances throughout the works.

In such shops air is used to operate riveting machines, punches, stay-bolt breakers, stay-bolt cutters, rotary tapping and drilling machines, flue rollers, rotary grinders,

* *London Engineering*, April 19, 1901.

rotary saw for sawing car roofs, pneumatic hammers, chisels and caulking tools, flue welders, boring and valve-facing machines, rail saws, machine for revolving driving-wheels for setting valves, pneumatic painting and whitewashing machines, dusters for car seats and the operation of switching engines about the yard. It is also used in the foundry for pressing and ramming molds, and for cleaning castings by the sand blast; but its greatest field of usefulness is its application to hoisting and lifting operations in and about the works.

New applications of compressed air are constantly being made, and each new use suggests another. This has a tendency to increase the number of appliances which are intended to be labor-saving devices, but in many cases the work could be done just as well and much more cheaply by hand.

A case in point is seen in an apparatus which was at one time in use on one of our prominent western roads. It was a sort of portable crane hoist which could be fastened to the smoke-stack of a locomotive, whereby one man could lift off the steam chest casing. The hoisting apparatus weighed about twice as much as the steam chest and took three men to put it up. When piece work was adopted two men easily lifted off the steam chest and this 'time and labor saving device' was relegated to the scrap heap.

While compressed air has been used to some extent for inducing draft in forge fires, it is unquestionably a very expensive method. Tests to determine this show that it costs twenty-five times as much to produce blast in that way as it would with a fan.*

The success and economy which has attended the use of compressed air in so many lines of work has led to its adoption in fields which are much better covered by electrically operated machines. While compressed air has been used under certain conditions very satisfactorily to operate pumps and engines, printing-presses, individual motors for lathes, planers, slotters, dynamos and other work, it does not follow that it is always an economical agent under these various uses, or that other methods could not be used even more satisfactorily in the majority of cases.

It has been proposed to use individual air motors in machine shops and do away with all line shafting, except possibly for some of the heavier machinery. This use of compressed air seems entirely outside the pale of its legitimate field; the general experience thus far indicates that rotary motors are not at all economical and generally are not as satisfactory as electric motors.

Exceptions are to be found in the small portable motors for drilling and similar operations, to which electricity is not at all adapted and where compressed air has been found to give excellent results. The saving obtained by the use of such portable drills as compared with a ratchet drill is very marked.

Although these tools are very successful they are still rotary motors, not exempt from some of the objectionable features which seem to be inseparable from them. It is not surprising, therefore, to find a tendency to employ reciprocating pistons and cranks in these portable machines and we note such tools weighing only forty pounds capable of drilling up to two and a half inches diameter.

While the field is to some extent limited, yet the uses of compressed air are certainly not few, and in many lines of work marked economy results from its use.

In most cases no attempt has been made to use the air efficiently; its great convenience and the economy produced by its displacement of hand labor have, until re-

* *Proc. Western Ry. Club*, 1898.

cently, been accepted as sufficient, and greater economies have not been sought.

In the matter of compression we still occasionally find very inefficient pumps in use, but manufacturers generally have found that it pays to use high-grade economical compressors. The greatest loss is that in the air motor itself. In a large number of cases it is impracticable or, at most, inconvenient to employ reheaters, and we find very generally that the air is used at normal temperature for the various purposes to which it is applied.

To obtain the most satisfactory results the air must be used expansively, but usually where the demand for power is intermittent no attempt has been made to reheat the air, and as a result the combined efficiency of compressor and motor is quite low, varying in general from 20 to 50 per cent. While low working pressures are more efficient than high, the use of such pressures would demand larger and heavier motors and other apparatus which is undesirable.

The advantages of higher pressures in reducing cost of transmission are also well recognized, and the present tendency is to use air at 100 to 150 pounds instead of the 60 or 70 pounds of a few years ago.

By reheating the air to a temperature of about 300° F., which may often be accomplished at small expense, the efficiency is greatly increased; in some cases this has been shown to be as high as 80 per cent. While the lower pressures are yet more efficient, the loss due to higher compression is not serious.

If air be used without expansion it will be seen that there is a material loss in efficiency; but, on the other hand, if it be used expansively without reheating, trouble may be experienced, due to the drop in temperature below the freezing point. If moisture be present this will cause the formation of ice, which may clog the passages if proper precautions are not taken to prevent it. The low temperature will not in itself cause trouble; if, therefore, the moisture which the compressed air holds in suspension be allowed to settle in a receiving tank, placed near the motor or other air apparatus and frequently drained, less trouble will be experienced from this cause.

While it may be impracticable to reheat the air in certain cases, yet there are many situations where a study of means to overcome the losses referred to would result in marked economies.

The greater adaptability of compressed air to various purposes causes its use to increase along with that of the electric motor, for it has a different field of usefulness, independent of power transmission; at the same time when the requirements are properly observed in its production and use, its economy as a motive power in special cases compares favorably with other systems. With a better knowledge of the principles involved we may expect much better results than have yet been attained.

But compressed air possesses so many advantages that, however inefficient it may be as a motive power, its application to shop processes will be continually extended as its usefulness becomes better known.

Mention has been made of the use of hydraulic motors as a factor in the subdivision of power, but these are being used to such a limited extent for this purpose that we shall not consider them at the present time.

There is, however, a growing field of usefulness for hydraulic power in manufacturing operations which is peculiar to this agent alone, namely, its use in forging and similar work. Where hydraulic power exists for this purpose it is also generally used for a variety of purposes which could be accomplished just as well, and often more

economically, by steam or compressed air; but in forging operations where heavy pressures are required hydraulic power is infinitely better than either.

The compressibility of air is an objection in many lines of work, and it is now well recognized that the effect of a hammer blow is oftentimes merely local. As Mr. H. F. J. Porter has so ably shown elsewhere,* the pressure applied in forging a body of iron or steel should be sufficient in amount and of such a character as to penetrate to the center and cause flowing throughout the mass; as this flowing of the metal requires a certain amount of time the pressure should be maintained for a corresponding period.

Hydraulic pressure, instead of a hammer, should, therefore, be used to work it into shape. Under its action the forging is slowly acted upon and the pressure is distributed evenly throughout the mass, whereas under the high velocity of impact of the hammer the metal does not have time to flow, and thus internal strains are set up in the mass, which may cause serious results, especially with certain steels which have not the property of welding.

Besides the fundamental defects incident to the method, it is very troublesome to use a hammer in certain lines of work, on account of mechanical difficulties of manipulation.

The quality of the steel is very much improved by the processes of hydraulic forging, and we find a marked tendency to substitute this method in a wide variety of work in which presses are employed varying in capacity from 20 tons to 14,000 tons.

We are all familiar with the fact that the magnificent 125-ton hammer made by the Bethlehem Steel Co. lies idle, while the work for which it was intended is done by a 14,000-ton hydraulic press operated by an engine of 15,000 horse-power; it may not be so generally known, however, that all forgings except small pieces are done on hydraulic presses, and that the largest hammer in actual operation is one of 6 tons capacity in the blacksmith shop.

The pressure used in these works is 7,000 pounds per square inch, but the present tendency indicates the use of a so-called low-pressure transmission service under a pressure of 400 or 500 pounds, with an intensifier at the press which raises the pressure to 2,500, 5,000, 7,000 pounds, or whatever may be required.

In this case the lifting and lowering of the ram of the press is effected by low-pressure water, so that the cylinder always remains filled, and the high pressure is only brought to bear the moment the dies come in contact with the pieces to be forged. The intensifier is built in multiple, which permits of a variable force to suit the work to be done; its action and control are extremely simple, and results are produced which show a marked increase in speed and a decided economy in operation. Some of the recent German hydraulic forging machines equipped with intensifier operate at a speed of forty to seventy strokes per minute, on finishing, and twenty to thirty strokes per minute for the heaviest work.

The success which has attended the use of hydraulic power in forging is causing it to be applied to other and similar work to an increasing extent. In boiler works, railroad and locomotive shops, bridge works and ship-yards it is used along with compressed air, but where heavy pressures are desired hydraulic power is greatly to be preferred; hence we find it operating machines for punching and shearing heavy plates and sectional beams, riveting machines, stationary and portable, flanging and bending machines, tube upsetting ma-

* *Trans. A. S. M. E.*, Vol. XVII.

chines, wheel and crank-pin presses, lifting jacks and hoists of all kinds.

For heavy boiler work hydraulic riveting seems especially well adapted, as an intensity of pressure can be brought to bear upon the plates which is obtained by no other method.

We have already stated that compressed air as now used without reheating is not at all efficient as a source of motive power, since the combined efficiency of compressor and motor, even under favorable conditions, is not more than 50 per cent. of the available energy put into the compressor. In other cases the efficiency is as low as 20 per cent.

In the transmission of air, within reasonable limits, the loss in transmission if the pipes be tight need not be considered, for although there is a slight loss in pressure due to the frictional resistances of the pipes, yet there is a corresponding increase in volume due to drop in pressure, so that the loss is practically inappreciable.

There should be no comparison between the cost of power by compressed air and its brilliant rival, electricity, since each has its own field of usefulness, yet it may be interesting to note for our present purposes the efficiency of electric power. A modern shop generator belted from an engine will have an efficiency of about 90 per cent. when working under favorable conditions, but as the average load is ordinarily not more than two thirds full load, and often much less, the efficiency will not usually be more than 85 per cent. Since the engine friction was added to the losses in compression, so also it should be considered here, in which case the efficiency of generation will lie between 75 and 80 per cent. With a three-wire 220-volt system, which is very suitable for ordinary shop transmission when both light and power are to be taken off the same dynamo, the loss in transmission need not be more than 5 per cent., so that the efficiency at the motor terminals will not be far from 75 per cent. With motors running under a nearly constant full load the efficiency of motor may be 90 per cent.; but with fluctuating loads this may fall to 60 per cent. at quarter load. In numerous tests made by the speaker the average load on several motors in machine shops has been only about one third of the rated capacity of the motor. It is interesting to note that in tests made at the Baldwin Locomotive Works it was found that with a total motor capacity aggregating 200 horse-power, a generator of only 75 kilowatts was sufficient to furnish the current, and ordinarily only 60 kilowatts, or 40 per cent., was required. At the present time there are in use at these works upwards of 300 motors, with a combined total capacity of 2,200 or 2,300 horse-power; whereas the generator output is only about 500 kilowatts.

Under those conditions, where the driven machines are not greatly over-motored, we may assume a motor efficiency of 80 per cent., which may be less or greater in individual cases. The combined efficiency, then, of generator and motor working intermittently with fluctuating loads will be about 60 per cent. of the power delivered to the engine.

For greater distances than those which obtain in plants of this character the loss in transmission will be greater, and higher voltage must be employed in order to keep down the line loss. While it is possible to put in conductors sufficiently large to carry the current with any assumed loss, yet the cost of the line becomes prohibitive with low voltage.

Where cheap fuel is available it is found in most cases that electric power can be generated at the works more cheaply than it can be purchased from a central station;

especially is this the case if the exhaust steam be used for heating purposes. In isolated plants the cost of transmission is very small as compared with the total cost of generation; whereas in the average central station the cost of transmission, which includes interest and depreciation on pole line, usually constitutes a large percentage of the operating cost.

In those localities where the cost of fuel is high, electric power can often be purchased more cheaply from a central station which obtains its power many miles distant and transmits it electrically to a convenient distributing center, where it is used for power and light.

The recent development in electrical transmission is very marked, and one constantly hears of some new achievement more wonderful than anything previously accomplished. Distances have been gradually increased until it is now possible to transmit electrical energy economically and in commercial quantities up to 150 and even 200 miles.

There has been a steadily increasing tendency to raise the line voltage in such transmissions, and to-day we find in successful operation voltages as high as 40,000 and even 60,000 as compared with the 4,000 and 6,000 volts of a few years ago.

As pointed out by Mr. A. D. Adams,* so far as present practice is concerned the limit of use of high voltages must be sought beyond the transformers and outside of generating and receiving stations. As now constructed, the line is that part of the system where a final limit to the use of higher voltages will first be reached.

In order to avoid the temporary arcing and leakage between the several wires it is necessary to place the wires a considerable distance apart, which, with higher voltages, may lead to a modification in construction of pole line. The plan of substituting a series of steel towers about 90 feet in height and 1,000 feet apart is being seriously contemplated.*

In this case it is proposed to suspend the wires from tower to tower and separate them about nine feet apart. While expensive in first cost, it is thought that the satisfactory working of the system and freedom from breakdown, with the low maintenance and depreciation charges involved, would warrant the investment.

A more serious difficulty is found in the insulator, which is generally looked upon with distrust for the higher voltages in use to-day. With a more perfect insulator there would appear to be no good reason why the present maximum voltages should not be exceeded.

The possibility of electrical transmission thus permits of the utilization of available sources of power at great distances from the center of distribution; but while it is interesting to know that a certain amount of power may be transmitted a given distance with a high degree of efficiency, it is more important to know whether the same amount of power could be obtained at the objective point more economically by other means.

It has been suggested that the future of long-distance transmission depends largely upon the development of oil as a fuel; but at the present time the outlook for oil fuel in general competition with coal or long-distance transmission is not encouraging; while the development of the Texas and southern California oil fields has increased the visible supply and brought about increased activity in the use of liquid fuel, yet it is doubtful whether the advantages would be sufficient to cause it to come into general use as a fuel, since with a limited production and an increased demand for

* *Eng. Mag.*, October, 1902.

* Geo. H. Lukes in *Trans. Assn. Edison Illuminating Companies*, July, 1902.

this and other purposes the cost would be correspondingly increased.

A number of railroads contiguous to the oil-producing centers have equipped their locomotives to burn this fuel, and it is used to some extent to fire marine boilers, and with great satisfaction; since its displacement for a given heating value is only about one half that of coal, and the labor cost is materially reduced.

It is also used quite extensively in certain sections of the country as a steam producer in power plants, but it is hardly probable that liquid fuel will be a serious competitor of coal, notwithstanding its many advantages. At the present time, as far as power for manufacturing plants is concerned, it is largely a question of transportation, whether oil can be laid down and handled at a given point more cheaply than coal. It is probable, however, that oil fuel will supply a local demand in certain sections where transportation charges, and possibly insurance, will permit its use at a low cost, and it is in this connection that it may become a competitor of electrical transmission.

One interesting phase of the power problem which forcibly presents itself to the engineer at the present time is the vast possibilities possessed by the modern combustion engine, which includes the various types of gas- and oil-engines. While its use as a motor in industrial establishments has been somewhat limited, yet there is a marked tendency to employ the gas-engine in manufacturing works, and a consideration of its advantages and cost of operation, together with its high thermal efficiency and possibility of still further improvement, indicates that, for a great many purposes, both steam-engines and electric motors may be ultimately replaced by gas-engines.

While the first cost of electric motors in the smaller sizes is considerably less than the cost of well-made gas-engines for similar capacities, the saving during the first six months of service, due to the more economical operation of the gas-engine, will often more than compensate for the difference in first cost.

That the gas-engine in both large and small sizes has reached a point in its development where it can fairly rival the steam-engine in reliability and satisfactory running qualities there can be no question. In point of fuel economy, a gas-engine of moderate size is on a parity with the largest triple-expansion steam-engines, and will give a horse-power on less than one pound of fuel.

The high price of gas in this country has contributed largely to those causes which have prevented a more common use of the gas-engine as a motor. For this reason the gas-engine has generally been used, not so much because of its high efficiency as a thermodynamic machine, but rather on account of its convenience and saving in labor. It is true that natural gas is cheap, but it is equally true that natural gas is not generally available.

It is to producer gas that we must look for any marked increase in the use of the gas-engine. Fortunately the manufacture of producer gas has reached a high state of development, and there are now in successful use several processes by which power gas can be made from cheap bituminous coals as well as anthracite and coke. The leanness of such gases renders them less effective per cubic foot of gas, as compared with the richer coal gas or even water gas; but this difference is more than compensated for by the low cost of production. It is upon such power gas that the commercial future of the gas-engine as a general motor depends.

A prominent factor in gas-engine practice which has attained a high degree of development in European practice is the

small gas producer. These generators are very simple in operation and furnish a convenient and economical means of obtaining power at a much lower rate than with the ordinary city lighting gas. Generally small anthracite coal or coke is used, but several methods employ bituminous coal, lignites or wood. With bituminous coal, means must be provided for removing the tar and ammonia and other products of distillation.

The process of generation in some of the more recent producers is entirely automatic and depends upon the demand of the engine, so that no storage capacity is required. The economy of these small producers is shown by tests which give one horse-power on a 16-horse-power engine with a consumption of only 1.1 pound of fuel. For engines above forty horse-power one horse-power can be obtained on seven eighths pound of fuel.

The gas-engine industry received a signal impetus when it was discovered that blast furnace gases could be readily utilized direct in combustion engines without the intervention of boilers and without any special purifying processes. A still more important circumstance which is far reaching in its results is the fact shown by Professor Hubert, of the Liége School of Mines, that the superior economy of the gas-engine enables equal power to be obtained with 20 per cent. less consumption of furnace gas than was formerly used in the generation of steam.

The successful employment of large combustion engines in this way utilizes vast sources of power which a few years ago were allowed to go to waste or at most were used very inefficiently.

The high thermal efficiency of the gas-engine has long been recognized and the possibility of further development is a promising factor in this field. The already accomplished efficiency of 38 per cent. reported by Professor Meyer, of Göttingen, greatly exceeds the maximum theoretical efficiency of the steam-engine and more than doubles its actual best obtainable working efficiency, but the end is not yet.

With higher compression even greater efficiencies may be expected. But with high compression there is danger of premature explosion, due to the generation of heat in compressing the gas in the presence of oxygen; for this reason Herr Diesel compresses the air separately. Under a pressure of 500 pounds or more, which is used in the Diesel motors, the air becomes very hot and readily ignites a charge of liquid fuel which is injected into the compression chamber. There is no explosion; combustion occurs while expansion goes on and the heat generated disappears in the form of work.

Efficiencies of 30 per cent. or more have been obtained with blast furnace gases which contain a very small percentage of hydrogen, and this with the high rates of compression which can be carried has led to the advocacy of non-hydrogenous mixtures in large engines. Certainly very high rates of compression may be had with a non-hydrogenous producer gas without fear of premature ignition, and it has the additional advantage of economical production.

The practice of making the cylinder in combustion engines act alternately, first as air compressor then as motor, has the advantage of greater simplicity, but it means immensely larger engines for the same power, since the number of effective impulses is thus cut in two.

The danger of pre-ignition and consequent severe shock on the engine also necessitates very heavy construction in the smaller engines in order to obtain a reasonable degree of safety in operation.

Moreover, the smoothness of action is greatly retarded with this form of engine, especially if the governing is controlled by the 'hit-and-miss' method, in which the regulation is effected by varying the frequency of the explosions, thus causing great variations in the driving torque.

Various expedients have been employed to overcome these defects, such as the use of multi-cylinders and different methods of control, but the size and cost of engine have been increased rather than decreased. Notwithstanding these well-recognized defects in the four-cycle type of engine, it constitutes by far the largest class in use to-day of what may be called successful gas-engines.

More recently very satisfactory results have been obtained in the construction of two-cycle engines. In some of these we find separate pumps employed to compress the charge of gas and air, which ignites and burns as it enters the cylinder. Higher compression is thus obtained without fear of pre-ignition, and this permits smaller clearance spaces with attendant advantages.

If the engine is single-acting, an impulse is obtained every revolution, which thus insures better speed regulation, as well as double the power for a given sized cylinder.

The highest thermal efficiency yet attained, namely 38 per cent., has been secured with a two-cycle type of engine which compresses the air and gas in separate pumps to a nominal pressure of eight or ten pounds; the air under this pressure being used to scavenge the cylinder toward the end of expansion. After the unconsumed products of combustion have been forced out by the fresh air, the cylinder walls having been cooled thereby, a charge of gas is admitted and compressed to a pressure of 150 to 175 pounds per square inch and then exploded, as in the usual method. This engine is double-acting and receives a charge each side of the piston; thus two impulses are received each revolution, in a manner precisely similar to that of a steam-engine.

Whether these engines will be as satisfactory for small motors remains to be seen. It is possible that the greater complication of details in the two-cycle types, as compared with the simpler four-cycle engine, will cause the latter to continue to give the greater satisfaction, at least for the smaller sizes.

At the last meeting of the British Association, Mr. H. A. Humphrey gave some interesting data concerning recent gas-engines, and the record is both remarkable and significant. The limiting size has rapidly grown during the past two years, as shown by the fact that one manufacturer is now constructing a gas-engine of 2,500 horse-power and is prepared to build up to 5,000 horse-power.

The development of the large gas-engine is closely connected with the evolution of the fuel gas processes, and it is noteworthy that the first gas-engines in England above 400 horse-power were operated with producer gas, while many of the large gas-engines in Europe have been built for use with blast furnace gas.

In August of this year (1902) two leading English manufacturers had delivered or had under construction over fifty gas-engines varying in size between 200 and 1,000 horse-power; but we have to look across the Channel for still greater achievements in this direction.

Neglecting all engines below 200 horse-power, we note that a classified list of gas-engines in use or under construction shows the remarkable total of 327 gas-engines capable of supplying 182,000 horse-power. This gives an average of about 560 horse-power per engine.

As compared with this we find from the last U. S. Census Report that, during the census year 1899, there were constructed in the United States 18,500 combustion engines having a total capacity of 165,000 horse-power, or only about 9 horse-power per engine.

Although this country has lagged somewhat behind Europe in adopting large gas-engines, there is evidence that this state of affairs will not exist very long, for a number of enterprising firms are already in the field prepared to build gas-engines up to any required size. One firm has already sold over 40,000 horse-power of large engines, most of them of 2,000 horse-power and several of 1,000 horse-power. Another firm has recently built two 4,000-horse-power gas compressors and also a number of 1,000-horse-power gas-engines.

The use to which these large engines are put is about equally divided between the operation of blowing engines for blast furnaces and the driving of dynamos for general power distribution; the tabulated list compiled by Mr. Humphrey for engines of more than 200 horse-power shows 99,000 horse-power for driving dynamos for light and power and 83,000 horse-power for other purposes.

While the gas-engine in the larger sizes is thus used extensively for the generation of electric light and power, a growing tendency is observed to use the gas-engines direct as motors.

A number of railroad and other machine shops have been equipped with moderate-sized gas-engines suitably located about the works, and in addition, thousands of horse-power are used in the smaller sizes for a wide variety of purposes, including village water-works, isolated lighting stations, and manufacturing plants of all kinds.

With the possibilities of high thermal efficiencies we may look with much hope upon the still higher development of cheap fuel gas processes that will bring the gas-engine into very general succession to the electric motor for many purposes, for it will doubtless be found that gas transmitted from a central gas-making plant at a manufacturing works into engines located at points of use will effect a material saving in the utilization of power over any existing methods.

It is not to be presumed that the gas-engine will displace either the electric motor or the steam-engine; each has its legitimate sphere of usefulness, and each will be more highly developed as the result of direct competition. Yet the economies already obtained indicate that the field of the gas-engine will be extended more and more into that of the steam-engine and the electric motor.

Many of the questions involved in this consideration are at the present time in a transitional stage. The reciprocating steam-engine has reached a high state of development, but it is not probable that it has attained its highest degree of perfection. While an economy less than $9\frac{1}{2}$ pounds of steam per horse-power-hour has been obtained, even better results may be anticipated; the use of high pressure superheated steam in compound, jacketed engines involves more perfect lubrication, and this may demand modification in existing valve types; however this may be, the outlook is promising for still higher efficiencies; whether this will mean cheaper power than can be obtained in other ways will depend upon many conditions.

In any case, and especially with intermittent or variable loads, it is not so much a question of maximum efficiency as it is economy of operation.

From this point of view the present activity in the construction and development of the steam-turbine is of interest to en-

gineers and power users. The steam consumption of a modern steam-turbine of moderate size compares very favorably with that of the better class of large reciprocating engines, but what is of greater importance is the evident superior steam economy under variable loads. The steam consumption per horse-power-hour varies little from one third to full load; at overloads the economy, as shown by numerous tests, may be even better.

This feature predestines the steam-turbine to the special field of electric lighting and power generation, where it must inevitably become a formidable rival of the larger-sized slow-speed reciprocating steam-engine.

It is a significant fact that immediately following upon the installation of the large 8,000-horse-power compound steam-engines at the central station of the Manhattan Elevated Railway, New York, we find three 5,000-horse-power steam-turbines under construction for the Rapid Transit Company, of New York.

The high rotative speed of the steam-turbine is a prominent factor in favor of its adoption in connection with electrical generators, since the cost of the generator end of the equipment ought eventually to be very materially reduced; but for many lines of work the high rotative speed of the present types of steam-turbine is prohibitive, nor can it be adapted successfully to belt driving, except by the use of gearing. However, it is fair to presume that the present limitations of the steam-turbine are not insuperable, and that the attention which is now being given to its development will evolve a more universal type of motor adapted to general power purposes with large and small units alike.

The economies already obtained with both the steam-turbine and the gas-engine have brought each into a prominence which is at least suggestive of the important developments that are taking place in methods of obtaining and using power.

JOHN JOSEPH FLATHER.

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*THE PERPLEXITIES OF A SYSTEMATIST.**

A FORMER Chairman of this Section gave utterance in his retiring address to the following frank expression of sentiment: 'So welcome to the old-fashioned systematist, though his day be short, and may he treat established genera gently!'

If this cheerful prognostication is to be realized, the perplexities of the systematist are of short duration at best, or worst, and it were better for us, in view of our impending doom, to come before you to-day with the historic 'Morituri te salutamus,' and then kindly but firmly retire to the oblivion so imminently before us.

But on second thought we find ourselves not at all in the mood to fulfil the expectations of the genial oracle referred to, and, indeed, very much alive and willing to continue in the struggle for existence, although an even worse fate than death is offered as an alternative when the same prophet predicts that 'the future systematic work will look less like a dictionary and more like a table of logarithms.' Of course there is no gainsaying the fact that those who prefer logarithms will have them, but I will also predict that the number who will choose the lesser evil of the dictionary will remain for an indefinite length of time very much in the majority, even if this choice dooms them to the outer darkness where the 'old-fashioned systematists' are to be relegated by the logarithm proposers.

However this may be, certain it is that there will always be need for the men who perform the hard and often thankless task

* Address of the chairman of the Section of Zoology and vice-president of the American Association for the Advancement of Science. Read at the Washington meeting, January 27, 1902.